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STANDARD FOR ENVIRONMENTAL SPECIFICATIONS

FOR SPACEBORNE COMPUTER MODULES

IEEE P1156.4

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by

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BACKGROUND

- Space environment differs from commercial and military environments
- No standard "Space Environment" exists -- each space mission is unique and environmentally tailored for each mission
- Futurebus+/S needed space environment defined -- activity accomplished concurrent with development of IEEE 896.10
- The Bus Architecture Standards Committee of the IEEE Computer Society recognized. the need for an environmental standard for Spaceborne Computer Modules that could be adapted to other spaceborne electronics
- Taken on as an additional task of the Futurebus+/S working group

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DEFINING THE SPACE ENVIRONMENT

- Problems in identifying a "Standard" Space Environment:
  - Module (Board) environment dependent on box level environment
  - Box environment dependent on spacecraft level environment
  - Spacecraft environment dependent on mounting in launch vehicle as well as the mission
  - Others
- Special considerations are generally necessary for the Ground/Prelaunch Handling, Launch Environment, or Orbit (or Deep Space)

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DEFINING THE SPACE ENVIRONMENT (Cont.)

- **Some Factors that influence the Space Environment:**
  - **Mission Type: Launch Vehicle, Satellite, Deep Space Probe**
  - **Mission Duration: Few minutes to 13 years (or more)**
  - **Orbit Altitude: LEO, MEO, GEO, Deep Space**
  - **Orbit Inclination: Equatorial, J?rograde, Retrograde**
  - **Orbit Shape: Circular, Elliptical, Sun Synchronous**
  - **Launch Vehicle: Atlas, Delta, Titan, Shuttle, Ariane, Pegasus, etc.**

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SPACE ENVIRONMENT PERFORMANCE LEVELS

4.1 Performance Level I: **Nominal environment, primarily intended for missions with relatively benign thermal cyclic, mechanical and radiation environments. This is the least demanding of the three levels. A short lived low earth orbit spacecraft placed into orbit by a launcher with a "soft ride" might be a typical application.**

4.2 Performance Level II: **Extended exposure environment, primarily intended for missions of longer duration with more severe thermal cyclic, mechanical vibration and radiation environments. This performance level has more demanding requirements than level I, but less demanding requirements than level 111.**

4.3 Performance Level III: **Extended exposure environment with severe thermal cycling and radiation environment. Although some requirements may overlap level II (notably shock and vibration), other requirements are more severe than the other two levels.**

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APPLICATION

- Originally designed to provide general environmental withstand conditions for the space application profile of Futurebus+.
- Since it does specify minimum environmental withstand conditions applicable to Spaceborne Computer Modules (and all components attached to the modules), it could also apply to spaceborne electronic equipment in general. If specifications are less restrictive than those listed in P1156.4 -- neither supplier nor user may claim compliance to P1156.4.

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TEST APPROACH

- **Performance levels contained in standard:**
  - **Non-operational: Temperature, Pressure, Relative Humidity**
  - **Operational: Temperature, Pressure, Delta Pressure, Relative Humidity, Pyrotechnic Shock, Random Vibration, Radiation (Total Dose, SEE, etc.), Electromagnetic Interference, and Electromagnetic Compatibility**
- **Military Specification Test Procedures identified consistent with accepted space industry practice:**
  - **Qualification: Functional, Pyroshock, Random Vibration, Thermal Cycling, Thermal Vacuum, Relative Humidity, EMI/EMC**
  - **Acceptance: Functional, Random Vibration, Thermal Cycling, Burn In**

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DOCUMENT CONTENT/OVERVIEW

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- Table 2. Operating Conditions -- Thermal
- Table 3. Operating Conditions -- Dynamics
- Table 4. Radiation Conditions
- Example -- Dynamics Environment

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Standard for Environmental Specifications for Spaceborne Computer Modules

Draft: 1.4 October 28,1994

Sponsor

Bus Architecture Standards Committee

of the

IEEE Computer Society

Approved XXXX NN, 19NN

IEEE Standards Board

Abstract: Fundamental information on minimum environmental withstand conditions is provided. The intent is to achieve uniformity and reproducibility in the test conditions for all spaceborne computer modules that may make up larger systems and are purported to have a rated environmental performance level. The specifications pertain to both the natural and artificial environments to which spaceborne computer modules may be exposed. These conditions include, but are not limited to, thermal, mechanical, electrical, and radiation stresses.

Keywords: The Style *Manual says* that the IEEE *staff chooses these.*

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CLAUSE PAGE

6.1 Non-operating Conditions

Computer II1O(ILI]CS and components shall withstand, without damage, the non-operating environmental specifications listed in table 1 and described briefly below. All testing shall be performed without a shipping container unless otherwise specified.

6.1.1 Temperature

The module shall withstand external ambient temperature as low as -34°C, and as high as 7 1°C for all performance levels.

6.1.2 **Pressure**

The module shall withstand the ambient pressure requirements for all performance levels as shown in [able].

6.1.3 Relative humidity

The module shall withstand relative humidity ranging from zero to 95%, with no condensation for all performance levels.

Table 1- Non-operating conditions

Parameter	Test	Level I Nominal	Level II Extended Exposure	Level 111 Extended w/ Severe Rad. Thermal Cycles
Temperature	Qualification	-34°C to +71°C	-34°C to+71 °C	-44°C to +81°C
	Acceptance	Same as Qual	Same as Qual	Same as Qual
Pressure	Qualification	≤1E-5 Torr	<11:-5 Tori	≤1E-5 Torr
	Acceptance	Same as Qual	Same as Qual	Same as Qual
Relative Humidity	Qualification	0 to 95%, Noncondensing	0 to 95%, Noncondensing	O to 95%, Noncondensing
	Acceptance	NA	NA	NA

6.2. **Operating Conditions**

Computer modules and components shall withstand and maintain normal operation when subjected to the environmental withstand conditions and tests listed in tables 2,3, anti 4, and discussed briefly below.

6.2.1 **Temperature**

The module shall meet all performance requirements while Operating with a mounting surface temperature between the limits listed in (able 2.

Table 2- Operating conditions-thermal

Parameter	Test	Level I Nominal	Level II Extended Exposure	Level 111 Extended WI Severe Radiation
Thermal/ Vacuum	Qualification Levels	34°C to + 71°C	34°C to + 71°C	34°C to+ 71°C
	Cycles	One Cycle	One Cycle	One Cycle
	Dwell Duration	144 hrs hot/ 24 hrs cold	144 hrs hot/ 24 hrs cold	144 hrs hot/ 24 hrs cold
	Transition Rate	≤30°C per hr and no more than 10°C in any one minute	≤30°C per hr and no more than 10°C in any one. minute	≤30°C per hr and no more than 10°C in any one minute
	acceptance Levels	-34°C to + 71°C	-34°C to + 71°C	-34°C to + 71°C
	Cycles	One Cycle	One Cycle	One Cycle
	Dwell Duration	60 hrs hot/ 8hrs cold	60 hrs hot/ 8hrs cold	60 hrs hot/ 8 hrs cold
	Transition Rate	≤30°C per hr and no more than 10°C in any one minute	≤30°C per hr and no more than 10°C in any one minute	≤30°C per hr and no more than 10°C in any one minute
Thermal Cycles	qualification Levels	-34°C to + 71°C	-34°C to + 71°c	-34°C 10+ 71°C
	Cycles	200	500	10(K)
	Plateau Dwell Duration Hot[a] Cold	1 hour Note b	1 hour Note b	1 hour Note b
	Transition Rate	up to 10°C/min	up to 10°C/min	up to 10°C/min
	Acceptance Levels	-34°C to + 71°C	-34°c to+ 71°C	-34°C to + 71°C
	Cycles	One Cycle	One Cycle	One Cycle
	Dwell Duration[b]	Thermal equilibrium	Thermal equilibrium	Thermal equilibrium
	Transition Rate	up to 10°C/min	up to 10°C/min	up to 10°C/min

[a] Minimum duration can be based on the appropriate failure physics. - See suggested practices Section 8.1, Thermal

b Minimum time, based on duration of functions] test.

'I'able 2- Operating conditions-thermal
(continued)

Parameter	Test	Level 1 Nominal	Level 11 Extended Exposure	l--ewe] 111 Extended WI Severe Radiation
Pressure	Qualification Acceptance	≤1E-5 'F'orr ≤1E-5 Torr	≤1E-5 Torr ≤1E-5 Torr	≤1E-5 Torr ≤1E-5 Torr
Rate of Change of Pressure	Qualification Acceptance	55 Torr/sec Not Applicable	75 Torr/sec Not Applicable	100 Torr/sec Not Applicable
Relative Humidity	Qualification Acceptance	o to 95%, Noncondensing Not Applicable	o to 95%, Noncondensing Not Applicable	o to 95%, Noncondensing Not Applicable

Table 3 - Operating conditions-dynamics

Parameter	Test	Level I Nominal	Level II Extended Exposu	Level III Extended w/ Severe Radiation
Pyrotechnic Shoc	Qualification	15 G at 100 Hz; 1500 G from 1kHz to 10 kHz; Three shocks in each of three orthogonal axes, for a total of 9 shocks	30 G at 100 Hz; 3000 G from 1kH to 10 kHz; Three shocks in each of three orthogonal axes, for a total o 9 shocks	30 G at 100}Iz; 3000 G from 1kHz to 10 kHz; Three shocks in each of three orthogonal axes, for a total of 9 shocks
	Acceptance	NA	NA	NA
Random Vibration	Qualification	0.032 G^2/Hz at 20 Hz; 0.2 G^2/Hz rom 50 to 800 Hz 0.032 G^2/Hz at 2 kHz; 22.3 G_{rms} overall; Three minutes in each of three orthogonal axes	0.125 G^2/Hz at 2(Hz; 0.8 G^2/Hz rom 50 to 800 Hz ().1 25 G^2/Hz at 2 kHz; 31.5 G_{rms} overall; Three minutes in each of three orthogonal axes	0.125 G^2/Hz at 20 Hz; 0.8 G^2/Hz from 50 to 800 Hz; 0.125 G^2/Hz at 2 kHz; 31.5 G_{rms} overall; Three minutes in each of three orthogonal axes
	Acceptance	~.016 G^2/Hz at 2(J Hz; 0.1 G^2/Hz om 5010800 Hz;).016 G^2/Hz at 2 kHz; 11.1 G_{rms} Overall; One minute in each of hrcc orthogonal axes	).064 G^2/Hz at 20 Hz; ().4 G^2/Hz om 50 to 800 Hz;).064 G^2/Hz at 2 kHz; 15.7 G_{rms} overall; One minute in each Of hrcc orthogonal axes	).064 G^2/Hz at 20 Hz; ().4 G^2/Hz rom 50 to 800 Hz; 0.064 G^2/Hz at 2 kHz; 15.7 G_{rms} overall; One minute in each of three Orthogonal axes

Table 4- Radiation conditions

Parameter	Test	Level I Nominal	Level 11 Extended Exposure	Level III Extended WI Severe Radiation
Total Radiation[a] Dose	Qualification	20 Krads	100 Krads	1 Megarads
Module SEU Rate[b]	Qualification	$\leq 3 \times 10^{-3}$ SEUs/Day	≤7x 10-6 SEUs/day	≤7x 10-6 SEUs/day
Transient Upset Rate	Qualification	Not Applicable	Not Applicable	1x109 rad/s
Transient Survivability	Qualification	Not Applicable	Not Applicable	$1x10^{12}$ rad/s
SEL[c]	Qualification	Not Permitted	Not Permitted	Not Permitted
Neutron Damage	Qualification	Not Applicable	Not Applicable	5E12 Neutrons/cm^2 (1 MeV equiv.)

[a] The use of additional shielding to reduce the radiation level to qualify parts is acceptable with sufficient and demonstrable anal ysis considering the specific orbit in question.

b Module SEU rates are specified which are dependent on component selections. Qualification of components fOr SEU depends on the source of the panicles and thus the orbit. Level I SEUs are assumed to be due to energetic protons at the South Atlantic Anomaly and cosmic-ray heavy ions over the poles. Testing with heavy ions with sufficient range to penetrate the active area of integrated circuit with LETs above 1 MeV/mg/cm^2 with exposure to at least lx 106 particles/cm^2 per data point with enough data points to determine the SEU threshold (or maximum value where no SEUs were observed) and saturation cross-section with sufficient accuracy to permit the SEU rate to be accurately assessed using commonly applied modeling techniques. Decapping will be necessary. Testing with protons does not require decapping, but must be performed with energies greater than 30 MeV, with fluences of at least 1x1010 particles/cm^2. Total dose degradation (calculated from the stopping power of the protons and the fluence - at 30 MeV, 1x1010 protons/cm^2 results in an absorbed dose of 2.42 Krad (Si) and the influence on proton SEU rate will be monitored

[c] The qualification level is a demonstration of no SEL with exposure to 1 x 107 particles/cm^2 particles of sufficient range to penetrate the active area of the integrated circuit and with an 1 .ET of greater than 40 MeV/mg/cm^2. SEL that is non-destructive or does not impact long term reliability qualifies as long as a work-around technique is demonstrated that does not impact overall system reliability.

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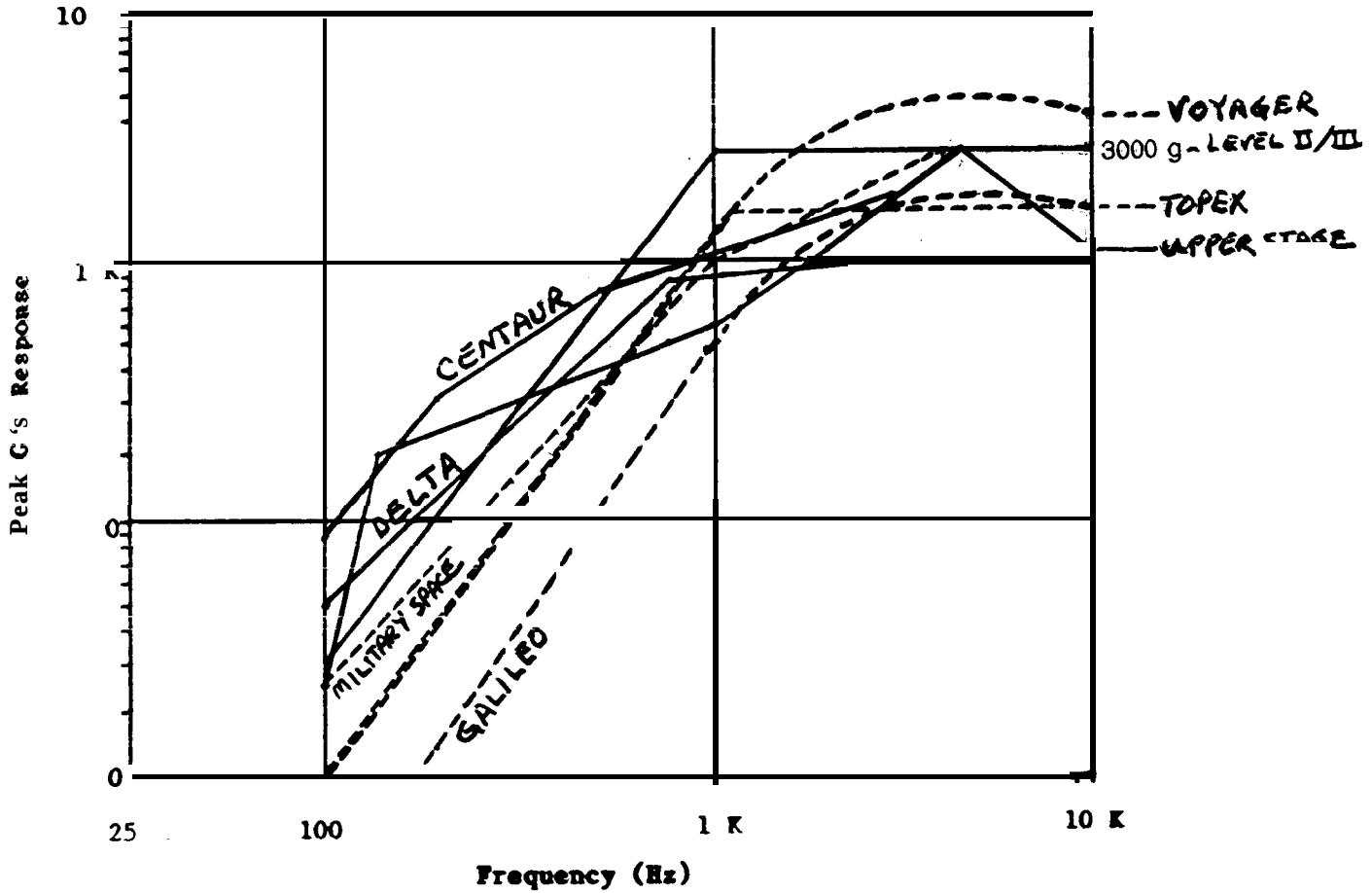
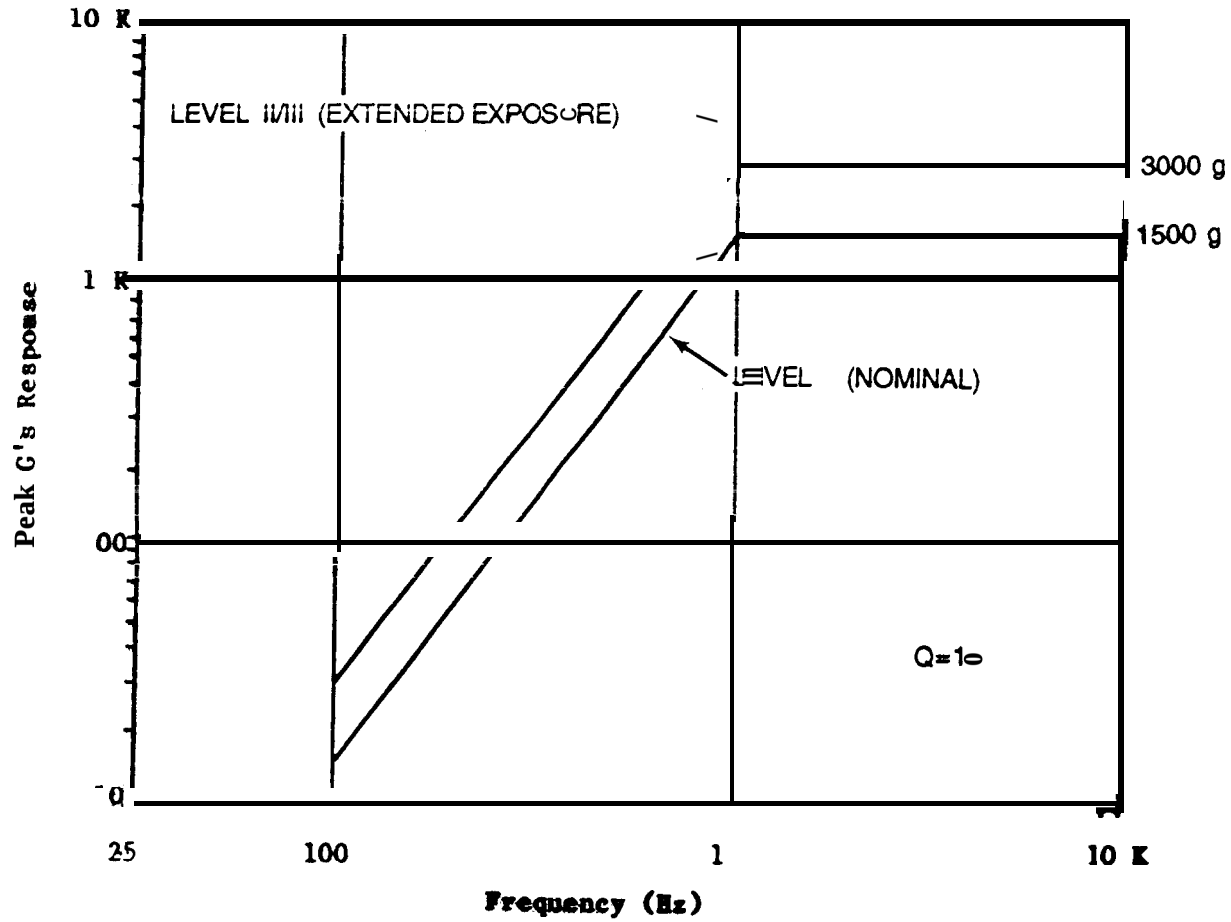
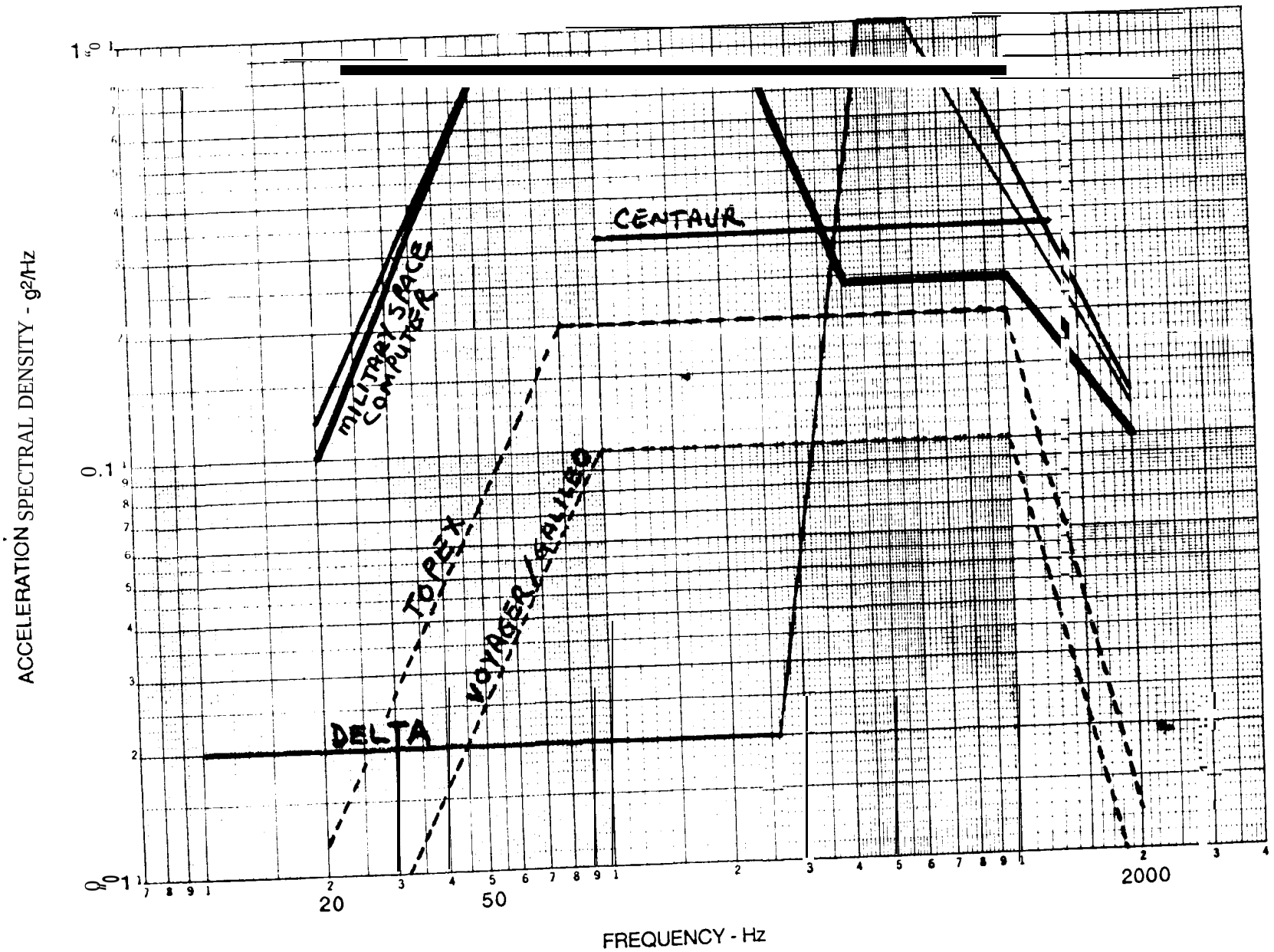
PYROSHOCK QUALIFICATION



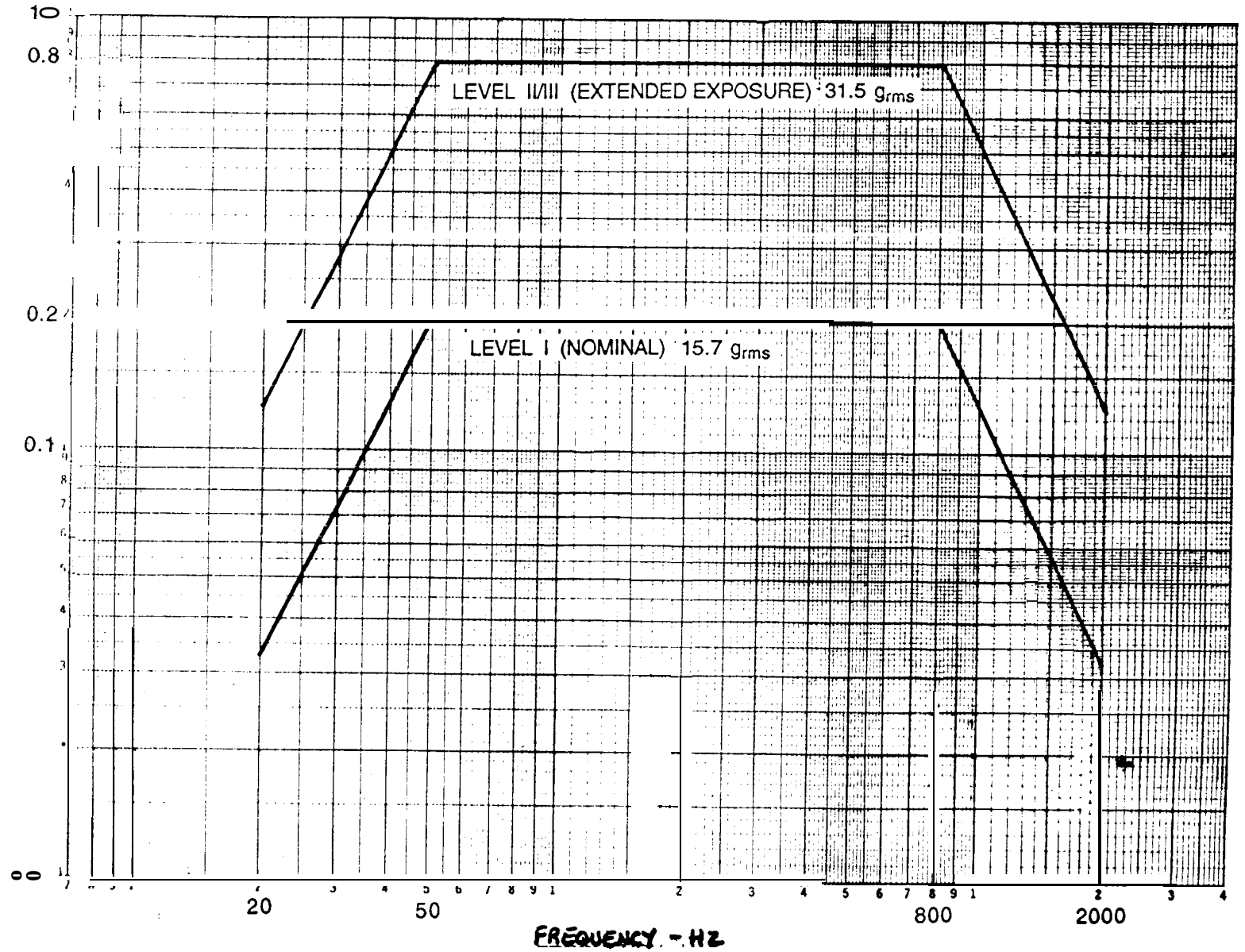
ENVIRONMENTAL SPECIFICATIONS FOR SPACEBORNE COMPUTER MODULES
PYROSHOCK QUALIFICATION



ENVIRONMENTAL SPECIFICATIONS FOR SPACEBORNE COMPUTER MODULES
RANDOM VIBRATION QUALIFICATION



ENVIRONMENTAL SPECIFICATIONS FOR SPACEBORNE COMPUTER MODULES
RANDOM VIBRATION QUALIFICATION



ENVIRONMENTAL SPECIFICATIONS FOR SPACEBORNE COMPUTER MODULES
RANDOM VIBRATION ACCEPTANCE